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Article

Mitigating Urban Visual Pollution through a Multistakeholder Spatial Decision Support System to Optimize Locational Potential of Billboards

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Abstract: Urban visual pollution is increasingly affecting the built-up areas of the rapidly urbanizing planet. Outdoor advertisements are the key visual pollution objects affecting the visual pollution index and revenue generation potential of a place. Current practices of uninformed and uncontrolled outdoor advertising (especially billboards) impairs effective control of visual pollution in developing countries. Improving this can result in over 20% reduction of visual pollution. This article presents a spatial decision support system (SDSS) to facilitate all the stakeholders (development control authorities, advertisers, billboard owners, and the public) in balancing the optimal positioning of billboards under the governing regulations. In terms of its technical implementation, SDSS is based on well-known geospatial open source technologies and uses an analytical hierarchy process AHP-inspired approach in spatial decision-making. It can help users through its category-specific user interface to identify potential sites to position new billboards and the selection of boards from existing sites based on a wide variety of characteristics. The observations of all stakeholders have been recorded through panel feedback to assess the system's initial effectiveness. The proposed system has been found functional in identifying hot spots for the focused management and exploration of the best suitable sites for new billboards. So, it helps the advertising agencies, urban authorities, and city councils in better planning and management of existing billboard locations to optimize revenue and improve urban aesthetics. The system can be replicated in other countries irrespective of spatial boundaries by incorporating jurisdictional rules and regulations.

Keywords: billboards; spatial decision support system (SDSS); visual pollution, optimal location; mobile-based data collection; open data kit (ODK); billboards management system

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1. Introduction

Rapid urbanization has affected visual pollution, deteriorating the quality of life in urban centres. Researchers have recently started exploring various dimensions of this new form of pollution [1–4]. Wakil et al. have labelled the “pollutants” as “Visual Pollution Objects (VPOs)” to refer to all kinds of manmade features along with their physical characteristics (placement, appearance, size, color, view and functional hindrance) that affect the visual quality of urban surroundings [5]. Portella has listed VPOs in the context of developed countries [1], while Sivaramanan [6] and Wakil [7] have identified contextual VPOs in developing countries. In their recent works, Wakil et al. have identified thirty-nine VPOs and ranked them based on contribution to the Visual Pollution Index (VPI), which is a scale of measuring visual pollution at a given node. After McMahon declared

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billboards to be “litter on a stick”, most scholars believe that outdoor advertisements and billboards are the most significant sources of urban visual pollution [8]. Wakil et al. estimate that outdoor advertisements and billboards contribute to 20.6% of the spatial visual pollution in a typical urban setting of a developing country. They are blamed for being the key source of highway crashes, mental health implications and cultural devastation [9–13]. A group of researchers believe that the lack of control and management of billboards and hoardings has destroyed the visual–physical environment of our cities [5,7,12,14–16]. With higher locational concentration, unsuitable sizes, varying heights, unbalanced colors and poor construction practices, they damage the socio–physical environment in urban centres [17].

On the other hand, billboards and hoardings are a considerably large revenue source for controlling agencies and their owners and advertisers [13]. Additionally, as a medium of communication, billboards are encouraged for advertising due to visibility, revenue generation, media effectiveness and tangible response [18]. In Lahore, Pakistan, billboards’ tax income was 75% of the total annual income of the municipal committee. Taylor has documented the role of billboards in the US economy [19]. Hence, a complete ban on outdoor advertisements is not a viable management option as it has economic implications.

Globally, various modes of regulatory response exist to handle outdoor advertisements. They include from a complete ban, mild management and loosely-coupled control. In terms of regulations, São Paulo has adopted a “clean city law” imposing a complete ban on billboards [20]. Simultaneously, others have tried to regulate this phenomenon in terms of placement, size, color and contents. Planning authorities in developing countries like Pakistan are struggling with the management of billboards and hoardings in urban areas and are introducing regulatory frameworks for effective management [17,21–26]. However, the regulating agencies lack a scientific approach, such as using spatial analysis to identify problem areas.

In developing countries, billboards are a necessary evil for controlling authorities but cash cows for advertisers. Advertising agencies hunt for locations offering more prolonged exposure and higher traffic in relevant communities. Currently, billboard choice selection is based on an advertising agency’s marketing staff’s judgment rather than any decision support system offering information-based scenarios. In such circumstances, decision support systems are often handy to resolve complex preference problems.

Regulatory bodies require support in identifying areas with a higher locational density of billboards to regulate future installation permissions. Together, advertisers need to identify sites offering good exposure to a maximum audience in relevant communities. This is important to highlight that the intended stakeholders such as the advertisement agencies (more precisely “media communication groups” or “media houses”) and controlling authorities (urban planners) have different objectives and competing requirements in out of home media management which has not been previously managed through a single interface spatial decision support system (SDSS). Hence, the SDSS is proposed as a bridge between urban space stakeholders. This study develops an SDSS which supports relevant stakeholders in their decisions by providing actionable information. It could help manage and control billboards such that maximum financial potential within the regulatory limitations can be exploited.

This study presents a novel tool for the relevant stakeholders where the SDSS involves inventories of existing billboards and hoardings and supporting spatial data of the case city through primary and secondary data collection. The SDSS aims to a) assist government bodies in regulating the location of billboards by maintaining linear density, size, and height of installations in the light of relevant regulations; b) assist billboard owners in selecting optimal sites for the installation of new billboards and hoardings; c) help advertisers in selecting suitable sites for an advertisement campaign based on the billboard site characteristics and neighborhood demographics.

2. Related Work

Keywords and semantic searches have been used for the scoping review on the development of literature about visual pollution in the major global databases including “Urban studies abstracts via EBSCO”, “Art and Architecture Complete”, “ScienceDirect”, “Web of Science”, “SAGE Research Methods Online”, “Scopus”, “Google Scholar”, “APAF: Australian public affairs (full text) via Informit”, “CrossRef” and “Microsoft Academic”. The results show an increase in the publications on the subject in the last ten years. All the published literature in the English language has been manually cleaned to remove duplicates, and a final list of 248 published works has been used for further study. The current state of research on the subject can be categorized into six major areas;

- (a) Conceptualization: this group of research works revolves around defining the terms and its various aspects [6,15,27–39].
- (b) Description of visual pollution: this group of research works explain the existence of visual pollution phenomena in different areas and contexts [2,6,40–65].
- (c) Pollution ingredients: the research work that describes the various physical objects and their conditions which result in the visual pollution [14,16,66–86].
- (d) Application: this category of research explains the application of the visual pollution concept in real-world [3,87–100].
- (e) Assessment/measurement/quantification: documents the methods of assessing, measuring or quantifying various aspects of visual pollution [5,7,12,17,101–124].
- (f) Regulation/mitigation/control: describes various methods of regulating, mitigating or controlling visual pollution or its pollutants in various countries [20,86,125–142].

In the past few years, research has demonstrated the application of geospatial technologies to study outdoor advertisements. Developed countries provide few examples where GIS-based tools have been implemented to identify optimal locations for outdoor advertisements [143,144]. Haidu et al. have worked on the spatial dimension for optimizing advertisements [145]. They believed that advertisements’ effectiveness in any area depends on demographics, socio-economic and educational characteristics, and infrastructure.

Luke et al. have applied GIS for explaining the spatial aspects of tobacco billboards in St Louis [146]. They have implemented spatial analysis to quantify the extent to which tobacco companies were placing billboards close to minority neighborhoods and schools. Similarly, Hillier et al. have noticed and explained the clustering of unhealthy outdoor advertisements around child-serving institutions [147]. He emphasized the need for regulatory provisions to keep outdoor advertisement boards’ locations away for such institutions. In Nigeria, private companies have maintained billboards’ spatial databases for the advertising industry (Spatial Technologies limited 2011). Likewise, in the USA, Europe and Canada, service providers have been using demographic data, traffic flow, elevation and exposure data for deciding the best locations and return on investment from outdoor advertisements [148]. Wakil has documented a tool used by planning authorities to identify areas (hot spots) with locational congestion for taking corrective measures [17].

However, most researchers have worked on two extreme ends; GIS utilization to help advertisers make profit versus GIS utilization to help planning agencies eliminate billboards. This research focuses on bridging this divide. It is based on the understanding that a balanced approach can be taken where planning agencies can implement restriction, but at the same time advertisers can identify the best location offering maximum return on investment with full compliance of applicable rules. Resultantly, it will significantly help planning authorities and the advertising industry in countries such as Pakistan. With better management of billboards, cities will have improved visual environments while the information-based advertisement industry will contribute positively to the national economy.

While building SDSS, research has suggested applying task-technology-fit framework (TTF) under such circumstances so that the user needs are well documented for all

potential users of the SDSS and system functions can be designed to best match the user requirements. The TTF theory has been extensively applied for establishing a correlation among the SDSS's functional abilities and the demands of the tasks to be performed [149,150]. In Pakistan's case, Hussnain et al. has applied TTF to conceptualize and build a GIS-based planning support system for urban planning functions [151,152].

Locational problems are often solved through multicriteria decision making. There are several methods to create the criteria weights, for instance, additive normalization method, Eigen-vector method, weighted least-squares method, logarithmic least-squares method, and fuzzy method. Chentao has used multicriteria decision making for site selection along a high-speed railway [153]. Analytical hierarchy process (AHP) is a multicriteria decision-making tool that helps decision-makers choose between alternatives [154–156]. It facilitates a decision-maker dealing with a complex problem with multiple inconsistent and subjective criteria [157,158]. In contrast to classical AHP, fuzzy AHP uses fuzzy logic which allows more accuracy on the evaluation of complex decision criteria. Fuzzy logic is preferred while handling imprecise, more complex data, and expressions for humans than the static mathematical equations and laws [159,160].

In different fields such as site selection of restaurant, hotels, shipyards, vehicle gas filling station, highways, airports, railways stations, railway tracts, metro bus stations, waste solid management sites, dumping zones, toll plazas and installation of solar parks or wind turbines, the multicriteria decision-making process has been used in similar situations [161,162]. Beskese et al. have reported the usefulness of fuzzy AHP in site selection of Landfill sites [163]. Noorollahi (2016), used the fuzzy AHP method with geographical location and climate conditions using 11 criteria. His study focused on the land suitability analysis for solar farms [164]. Furthermore, Asakereh (2017) has used the same technique to prioritize Khuzestan province's land in Iran to install solar photovoltaic farms, based on techno-economic and environmental aspects [165].

Similarly, Taibi et al. have experimented combining fuzzy AHP with GIS for an industrial site selection problem [166]. Sasan et al. has demonstrated the use of fuzzy AHP in parking lot site selection. They have justified fuzzy AHP application to solve this problem since parking lot site selection requires multicriteria decision making and this problem requires considering multiple competing factors such as economic value, social acceptability, and environment [167]. Rodney has integrated AHP, fuzzy logic and GIS for optimum site modelling [168]. Di Zio et al. have presented another way to resolve such problems by adopting a new technique, "real-time spatial Delphi". They have appreciated the potential of WebGIS for fast online consultations. In their method, Di Zio et al. present the experts with a geo-questionnaire to place a marker on the map (representing a suitable location) along with attribute questions. The online system calculates and shows a circle representing the convergence of all presented points. As the experts improve their input, the circle keeps on shrinking in the real-time and finally, the most suitable site is selected [169]. This method is advantageous to decide the locational occurrence of existing physical phenomena or a suitable location for future use when most of the knowledge is with the experts. However, in cases when the decision about a location has to be taken based on the predetermined attributes (as in our case; the location is primarily based on the traffic flow, road width, adjacent land use, regulatory binding etc.), AHP is more suitable than the spatial Delphi method.

3. Materials and Methods

This research is exploratory and applied in nature, adopting a case study approach to gain an indepth understanding of the subject. It follows a five-step process for developing SDSS; starting with reviewing regulatory documents regarding the control and management of billboards to build the knowledge module. All the prohibitive and primitive conditions associated with the outdoor advertisement of billboards were noted down for conversion into equations usable in the knowledge module of the SDSS. After that, the stakeholders' requirements were documented through focused group discussions with

subject matter specialists for task-technology fit framework. The needs so collected were transformed into the design and development of web-based SDSS using open-source tools. The primary data from billboards in the case study area was collected through a mobile-based data collection system to populate the database module. Finally, the SDSS application and utilization assessment for user feedback was conducted. Figure 1 illustrates the methodological framework.

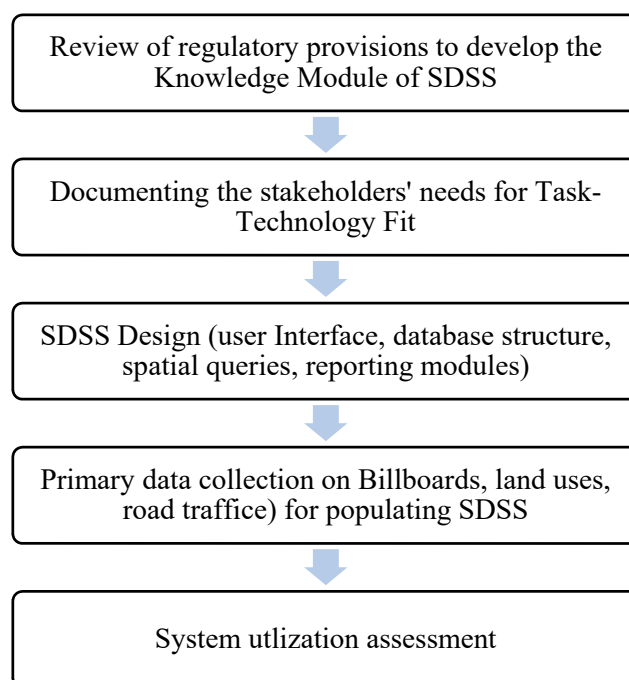


Figure 1. Methodological framework.

3.1. Case Study Area

Most of the previous works explore outdoor advertisements at street or block level. In contrast, for the deeper thematic study of the subject, this research has been conducted at a city-scale. Considering the urban dynamics of the developing world, particularly in South Asia, the city of Rawalpindi (the fourth largest city in Pakistan, with more than two million inhabitants at 33.5651° N, 73.0169° E) has been selected as the case study which offers the right mix of land uses, a heterogeneous population, rapid horizontal growth, and the existence of public and private governance mechanisms.

Being a twin city to the country's planned capital, this city (case study) offers a high diversity of land uses, billboards, and multiple controlling authorities as illustrated in Figure 2. The city spans over 300 square kilometres of the area. The control of outdoor advertisement and billboards falls under the Parks and Horticulture Authority, Rawalpindi (PHA) and district governments. In Pakistan's context, outdoor advertisements refer to various forms of ads, including banners, streamers, wall chalking, billboards, hoarding, moving platforms and signs. Hence, these two are dealt with separately in the regulations. Billboards, due to their size, physical location and structure are handled more specifically with guidelines closer to building control in nature. As per its website, the PHA takes responsibility for 180 advertisement board sites while the whole city has witnessed the mushrooming growth of billboards on every roof, wall or pole: Gomez calls this "Billboardization" [170] (See Figure 3).

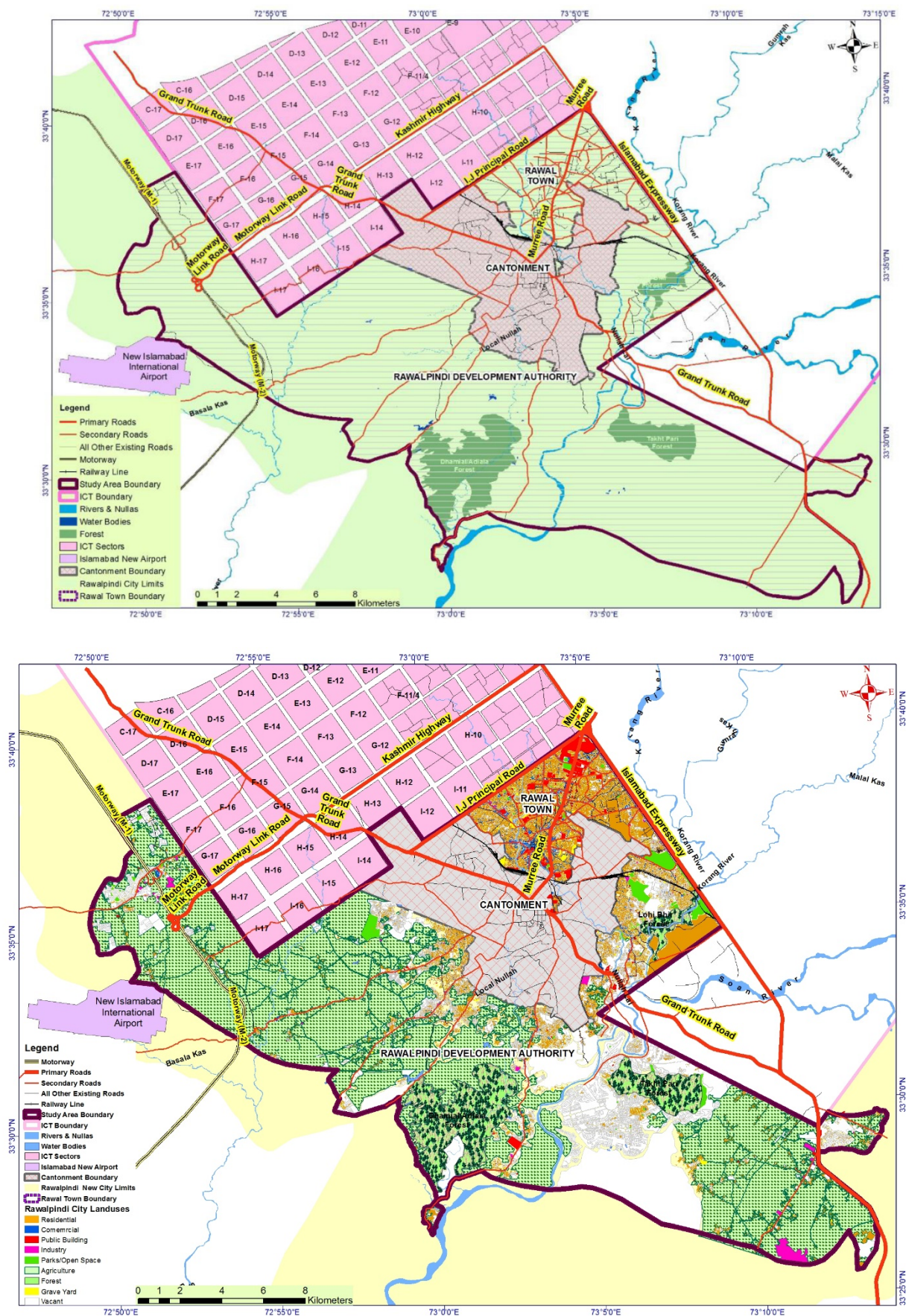


Figure 2. Study area boundary (top) and land use distribution (bottom).



Figure 3. A view of the declared commercial road representing unmanaged growth of billboards.

3.2. Review of Rules and Regulations Related to the Billboards and Hoarding

The design of the knowledge module of the SDSS is based on the study of all available and implemented legal documents (bylaws, policies, standard operating procedures, acts) regarding regularization and management of billboards/hoardings. In the case of the research area of study, a comprehensive review of the following regulatory instruments and planning permission guidelines was undertaken:

- Regulations for Outdoor Advertisements and Billboards by Parks and Horticulture Authority (PHA), 2013 [39];
- Punjab Local Government Act, 2013 [171];
- City District Government Faisalabad Advertisement Bylaws, 2013 [23];
- Punjab Outdoor Advertisements and Sign Boards Policy, 2008 by Punjab Housing and Urban Development Department (PHUDD) [24];
- Standard Operation Procedures (SoPs)-Hoarding in Cantonment Areas, July 2011;
- Military Lands and Cantt Hoarding Policy, 2012 [21];
- Advertisement, Signage Bylaws for Karachi 2003;

The regulatory information for development control at any tier mainly consists of permitting or prohibiting outdoor advertisements. In the case of permission, some governing rules are provided related to the locations (and their characteristics) where an outdoor advertisement can be permitted. In the case of this research, regulatory information relevant to permission and/or prohibition has been associated with the road links (polylines) based on the road size category. The study of relevant documents helped extract the list of system attributes required by administrative bodies to regulate billboards. For example, permission for installing the new billboard can be granted if: a. the spacing between two boards varies from 150' to 250' based on their location (primary or secondary road, highway) and size (20' × 60' or 30' × 90'); b. the proximity or remoteness of a billboard/ hoarding from certain land-uses. Further, it is used to identify the parameters which control new billboards' placement within the respective agency's jurisdiction area.

3.3. Mapping the Stakeholders and Their Competing Needs

This study used a panel of subject matter experts (SMEs) (n = 15) carefully chosen to represent the controlling agencies, advertisers and the community. They were engaged through an online tool to map the stakeholders' needs and requirements from the SDSS. The conceptual diagram of the SDSS was presented to the panel and they were requested to list the most essential needs related to tools, data and processing for the handling of billboards. Furthermore, the SMEs were asked to: (i) note down the information which they expect this SDSS should provide; (ii) list the queries/questions they would like to make through the SDSS; (iii) draw the flow diagram or a sketch of interfaces reflecting their mind maps about the SDSS functions. This helped in highlighting the competing and contrasting needs of the stakeholders.

3.4. Collection of Primary Data on Billboards/Hoardings (Location and Other Attributes of Interest) and Secondary Data

This stage involved collecting primary data from the field on the spatial location and nonspatial attributes of billboards and hoardings. Some of the critical elements are mentioned in Table 1.

Table 1. Data attributes.

Serial Number	Attributes	Categories
1	GPS location	Latitude, longitude
2	Type of structure	Wooden structure, iron structure monopole, multi post
3	Size of billboard	Small, 10 × 20, 20 × 30, 30 × 40, 30 × 90, Larger
4	Type of message	Commercial, religious, movie, public service message, harsh religious/political statement, political, indecent postures
5	Face directions	Single, double, vertical
6	Road frontage	In feet, number of lanes and flow direction
7	Type of advertisement board	Digital, mechanical, painted, mobile, poster, other
8	Number of display surfaces	Single facing, double facing (back to back), v facing triangle
9	Placement	Stand alone, on-wall, on the rooftop, other
10	Condition	Broken, leaning, torn off, normal and good
11	Ownership	Billboard ownership, contact details
12	Legal status	Permitted, nonpermitted (legal, illegal)

3.5. Design of Database Structure for SDSS

This step included the design and expansion of the spatial database of the SDSS so that it could deal with additional variables, particularly related to advertisers and their choices. Efforts were made to incorporate diverse factors including billboard locations, directions, associated roads, hourly traffic, demography and preferences.

3.6. Design of User Interface Prototypes and Workflow

Since the SDSS deals with multiple stakeholders including urban planning agencies, advertisers and board owners, relevant user interfaces have been developed so that the users without urban planning or GIS backgrounds may also make scenarios and adjust decision choices to obtain results. The entity–relationship (ER) diagrams are developed to streamline the workflow.

3.7. Technology Stack

The SDSS is based on open-sourced geospatial technologies. The technology stack being used to develop the portal encompasses a front end, LeafletJS (mapping library) used for visualization of billboards and their adjoining areas. The SDSS uses TurfJS (advanced geospatial analysis) for the spatial analysis of the data; in particular, it is used to filter billboards near roads, inside parcel blocks and in close proximity with other billboards. VueJS (JavaScript framework) is the front-end framework, which is being used for building the user interface, with the plugin Vuetify (the design component framework for VueJS) to give the application a material design appearance. The application is running on a VM instance on amazon cloud. Open street map (OSM) is used for the background base map, whereas Axios (HTTP client) is being used for data acquisition from the source GeoJSON files. The technology stack is illustrated in Figure 4.

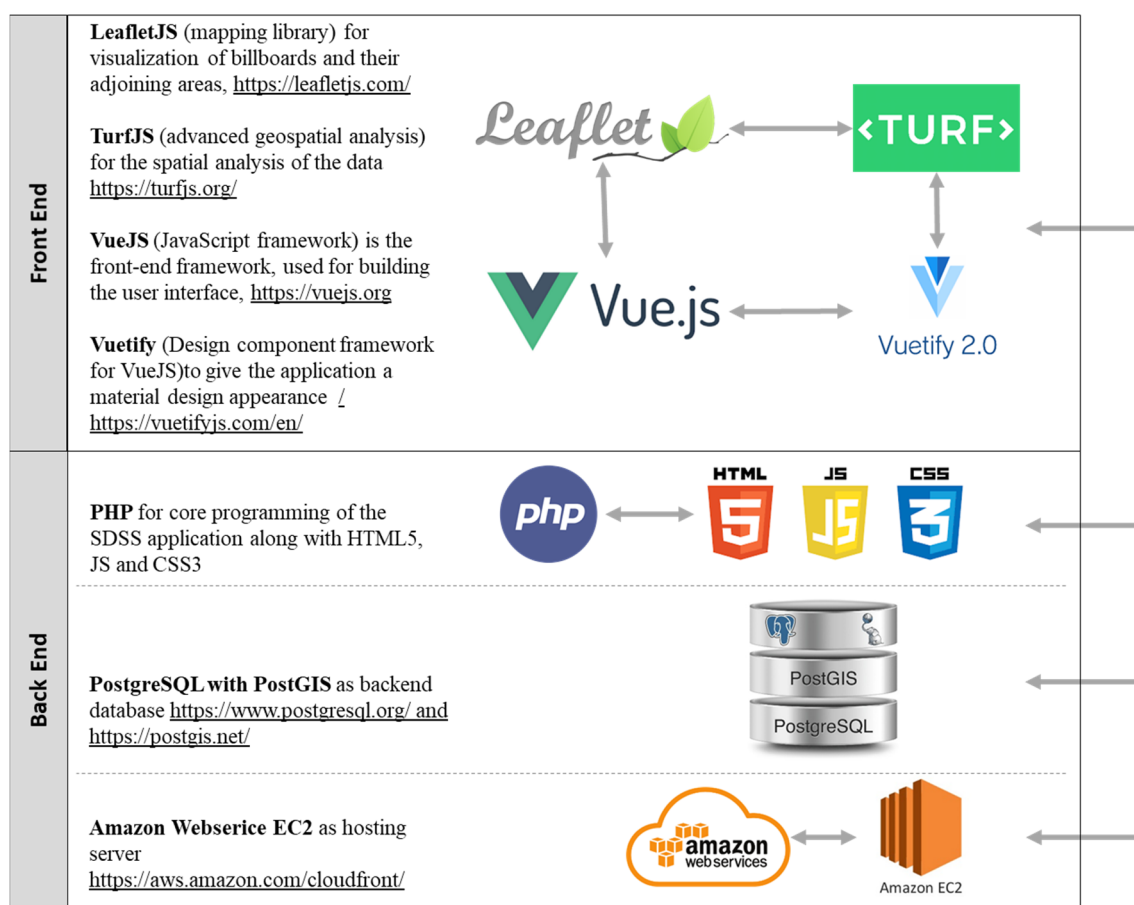


Figure 4. Technology Stack.

3.8. SDSS Assessment and User Feedback

After the lab-based development and testing of the SDSS, the panel was briefed about it in a workshop setting where they were oriented about its various functions and were allowed to use the SDSS and share their feedback. The panellists were asked to rank the various functions of the developed system against the initially listed tasks and record their satisfaction at a five-point Likert scale.

4. Results and Discussion

Considering the TTF framework, the following conflicting requirements of the user groups can be listed for the SDSS to handle (see Table 2).

Table 2. Requirements of different stakeholders.

Controlling Agency	Advertisers	Community
Need to know:	Need to know	
<ul style="list-style-type: none"> The location of installed billboards along with their attributes (size, placement, condition, type of message, faces, advertiser) If the billboard has been installed after approval If applicable fees and taxes have been paid If the placement complies with the regulations 	<ul style="list-style-type: none"> The location along with its general attributes with more focus on “availability” Which potential sites are available for billboard installation? The sites owned by other advertisers and if any of them are available for rent/sale The traffic flow on the adjacent road Gross Ratings Points (GRP) for each specific site Eyes on Impressions (EOI) for each site 	<ul style="list-style-type: none"> Need a mechanism to report if a billboard is causing visual pollution (due to its size, condition, or type of message)

Controlling Agency	Advertisers	Community
<ul style="list-style-type: none"> If the placement creates a linear point density of billboards which is higher than the permissible ratio 	<ul style="list-style-type: none"> Daily Estimated Circulations (DEC) for each site What is the demography of the neighborhood along with socio-economic class 	

There would be two sides of the desired SDSS for billboards: admin and user ends. The admin panel offers the functions for adding and editing data layers, visualization control and knowledge management while the user panel offers various visualization and query function associated to decision making (See Table 3 and Table 4).

Table 3. Functionalities available for different user levels.

Admin Panel	Users Panel
Adding/uploading of layers	Viewing/visualizing of layers (on/off, feature identification, measure distance)
Editing of layers	Calculating the point density of the billboards by showing it as a layer
Visualization control	Symbolizing (setting the opacity of layers and symbols by attributes such as classification of billboards by size, ownership, cost)
Knowledge management	Specification of the regularity controls as quantitative equations

The following two types of queries along with subqueries are also incorporated in the system:

Table 4. List of queries.

Query Types.	Query functions
Select queries on attributes (nonspatial query)	Select billboards where size is of a certain size e.g., larger than 90ft Select billboards where pole type is for example “Monopole” Select blocks where land use is “Residential”
Spatial queries (Select objects from a layer based on their proximity to some other layer.)	Select billboards which are within “x” meters of a selected road Select billboard which is within “x” of parcel block Select billboards which are within “x” meters of a point on a map

This study uses a variant of the AHP technique for its core computations while solving the selection problem. Though the overall process is driven and inspired by the workflow of traditional AHP, the variant is significantly different. In our case, the determination of the criteria for selecting locations for billboards is highly likely to be affected by the expert opinions and the conditions of the decision-making platform. As a result, the deterministic scale or crisp values can lead to misleading consequences. For example, some stakeholders want bigger sized screens for advertising, while others may want to acquire local citizens’ attention based on social class. Such circumstances create fuzziness in the decision-making process.

In the traditional AHP method, each actor/expert evaluates all the hierarchy criteria and alternatives, while in our case every single-user selects a criterion and then makes a pairwise comparison only for the alternatives under that criterion, which distinguishes the method from AHP. For pairwise comparison, a fully connected hierarchy is a key point of the traditional AHP method. However, it is not valid in our case, for example, to do a pairwise comparison between “Restricted” and “Allowed” under the criterion “Size of Billboard”. In our approach, the user chooses a criterion. However, in the general AHP

method, this is not so, because all the criteria must be compared pairwise. Despite its procedural matching with AHP, our method reflects a sequence where:

- Every single user selects a criterion and then makes the pairwise comparison only for the alternatives under it, and does not evaluate the other alternatives;
- Some alternatives are specific for a given criterion but not for the others;
- The elements of the hierarchy are not fully connected;
- The criteria are not compared pairwise;
- There is no weighting system of the criteria and alternatives;
- There is no estimate of the inconsistency of the matrices.

Figures 5 and 6 illustrate the main interface of the SDDS portal with attribute selection being made with the aid of filters. There is also an option to select different data layers (roads, land parcels), and detailed parameters are displayed upon clicking any billboard.

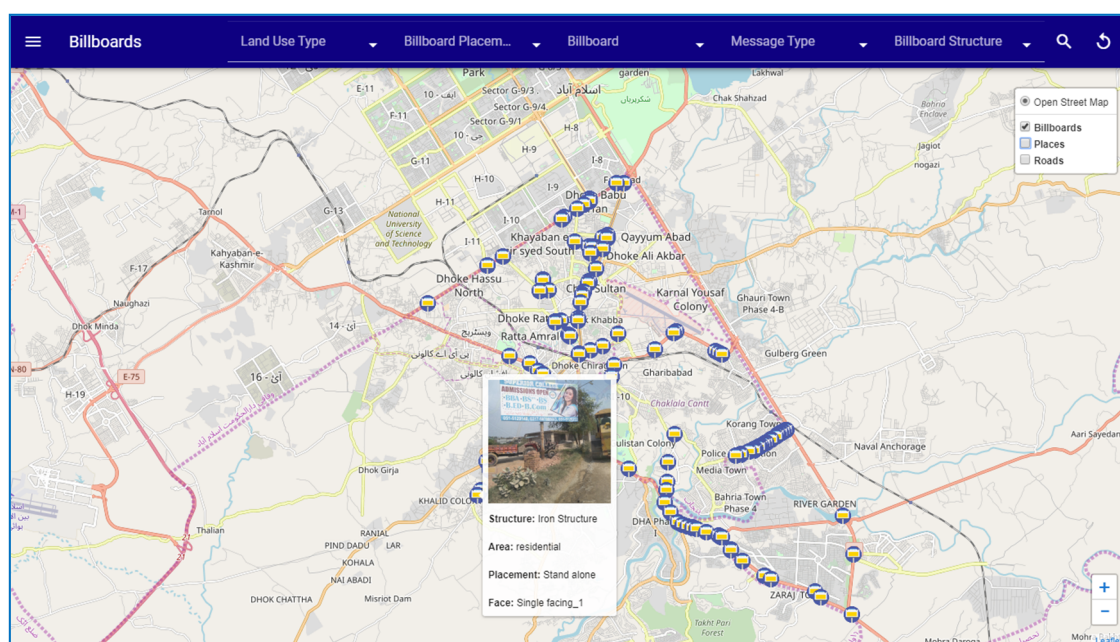


Figure 5. Basic system interface.

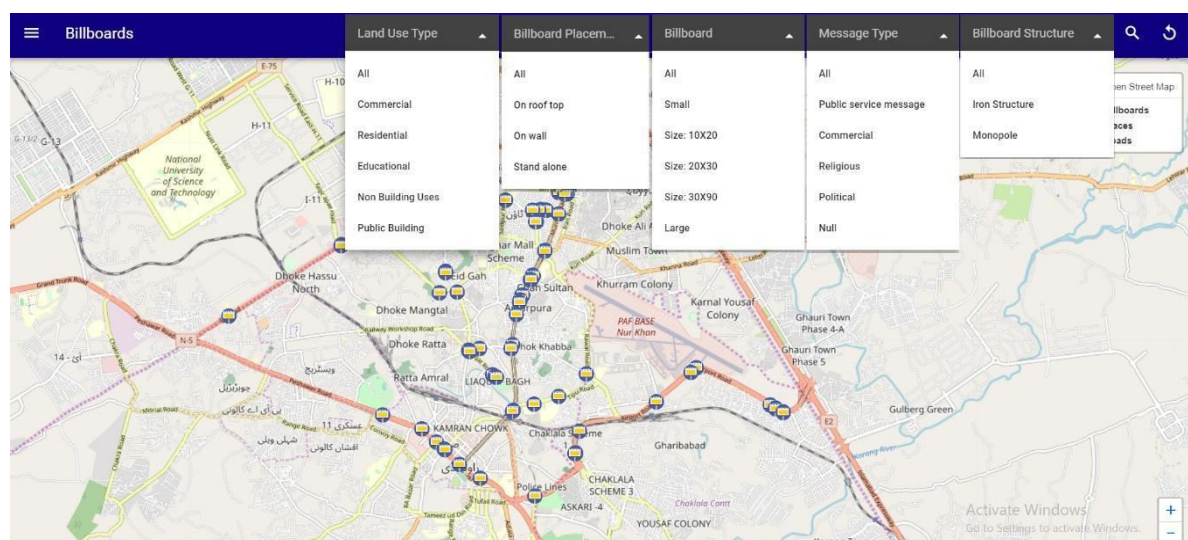


Figure 6. Attribute selection with filters.

Another GIS functionality, including buffer capability, is also added, which is the part of spatial queries performed on GIS dashboard. Buffers can be generated on billboards, roads and land parcels and the count of each billboard within that buffer range is displayed along with options of “buffer size”, “buffer color” and “type of buffer” (i.e., along the road, billboard or parcel).

The SDSS offers user-category-specific functions to the advertisers and controlling agencies in addition to the general query functions. For instance, if a user is logged in as an advertiser, he/she can choose from two broad methods of site selection; a) multilayer query selection or b) fuzzy AHP. In the case of AHP, the user can pick from the site characteristics which may be used for pairwise comparison. The characteristics of the billboard sites include size, gross ratings points (GRP), eyes on impressions (EOI), daily estimated circulations (DEC), the demography of the neighborhood, the dominant land use of the adjacent site, the traffic flow in peak hours and the adjacent road type. Based on the user selection, a comparison matrix is generated on the fly, which allows the user to compare and rank choices on a scale of 1-9. The user is asked to record their preferences among all the selected site characteristics, and the system computes the values among the shortlisted sites from the higher-level area of interest (see Figure 7).

You are logged in as Advertiser

Please select method of billboard site selection

☐ Multi Layer Query ☒ AHP

Select site characteristics for comparison

☒ Size ☒ GPR ☒ EOI ☒ DEC
☒ Area Demography ☒ Adjacent Road ☐ Traffic Flow ☐ Adjacent Land Use

Note: You have selected 6/8 factors for comparison.

Please provide pairwise comparison:

	A - wrt AHP priorities - or B?	Equal	How much more?
1	<input checked="" type="radio"/> Size <input checked="" type="radio"/> GPR	1	2 3 4 5 6 7 8 9
2	<input checked="" type="radio"/> Size <input checked="" type="radio"/> EOI	1	2 3 4 5 6 7 8 9
3	<input checked="" type="radio"/> Size <input checked="" type="radio"/> DEC	1	2 3 4 5 6 7 8 9
4	<input checked="" type="radio"/> Size <input checked="" type="radio"/> Area Demography	1	2 3 4 5 6 7 8 9
5	<input checked="" type="radio"/> Size <input checked="" type="radio"/> Adjacent Land Use	1	2 3 4 5 6 7 8 9

CANCEL **FIND BEST SITE**

Figure 7. System interface allowing a user (advertisers) to choose criteria and specify pairwise comparison for fuzzy AHP calculation.

In the case of a controlling agency, a different interface is presented to the user that matches their management functions. In this user case, AHP is particularly useful for exploring new potential sites to open for billboard installation. At the same time, routine management is mainly fulfilled by a multilayered query function. Figure 8 presents the screenshot where the user is allowed to use a graphical user interface to define criteria related to size, placement, condition, adjacency, site status, taxation and linear density.

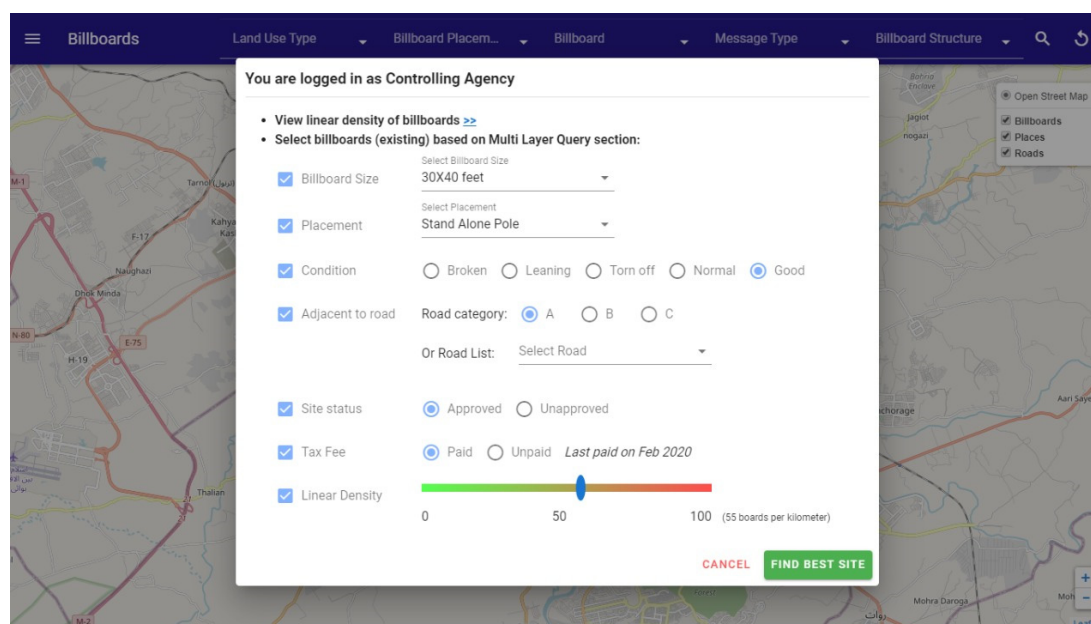


Figure 8. System interface allows a user (controlling agency) to select billboards based on multilayer query selection.

The initial feedback on the SDSS has been quite positive where the panellist has appreciated the SDSS with the strong hope that it will provide a practical solution to mitigate urban visual pollution. The government can use the tool for policy measures. The advertisers expressed higher satisfaction about the user interface and ease of site selection based on billboard characteristics and factors like GRP, EOI, DEC, demography and traffic. However, the need for ‘more frequent data’ or ‘real-time data’ on traffic arrived as a strong point for future updates.

5. Conclusions

Outdoor advertisements and billboards are a significant contributor to urban visual pollution. In many underdeveloped economies, a complete ban on billboards is not an available management option. The management of billboards in core urban centres is complex as it deals with competing requirements from different interest groups. On the development controlling agencies’ side, billboards are a source of visual pollution, and their locational placement requires considering legal, marketing and ethical considerations. On the other hand, advertisers have a different set of considerations, as they need their advertisements to reach relevant community groups in targeted numbers for revenue generation. This research presents a web-based spatial decision support system to balance the stakeholders’ competing requirements and offers them the ability to compare and contrast various indicators’ compositions to attain the most suitable decision. In addition to the generic selection tools, the system allows for user-specific criteria input for either multilayered query selection or fuzzy AHP. In the case of controlling agencies, they can use the SDSS to identify potential sites to offer for billboard installation.

On the other hand, advertisers may select, compare and rank a series of indicators through a pairwise comparison approach resulting in the precise selection of suitable sites for any advertiser. The system uses open source development tools to create a friendly user interface that allows users to rate, select, and choose decision-making criteria. This research implements an AHP-inspired approach with on-the-fly calculations in web environment resulting in a more comprehensive output. The developed system has been presented to the elected officials of the development authorities employing a hands-on workshop. The users’ initial feedback is highly encouraging as they find the system useful in achieving effective regulatory implementation and hotspot identification for the removal/control of billboard placement to enhance visual aesthetics in urban areas.

Furthermore, it helps advertisers taking informed decisions in choosing the right locations for the placement of the right messages to the targeted communities. They feel better control in exploring options, which may offer them optimum output by considering traffic flow, community socio-economic background, billboard type, direction and size. In a nutshell, it helps to attain a win-win situation between advertisers and controlling authorities and eventually benefits urban areas' residents, who enjoy the better visual feel. For replicating this system in other developing countries, the knowledge modules should be tailored as per the local context. In terms of its technical implementation, the SDSS uses AHP and fuzzy AHP approaches in spatial decision-making. In comparison to the previous works [17,172–175], this SDSS offers a more holistic solution to a broader spectrum of diverse stakeholder requirements. It is perceived that the system can be applied in other parts of developing world sharing the same characteristics as of the chosen case study in the research, particularly in developing countries facing the similar challenges of billboardization [170], institutional capacity, economy vs. aesthetic, and implementation loopholes.

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